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DEVELOPMENT OF NOVEL ARGON INJECTION METHOD TO AVOID TUNDISH NOZZLE CLOGGING A REVIEW

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ABSTRACT

Tundish nozzle clogging is a long standing issue ever since the continuous casting process has been introduced. Tundish nozzle is also called as Submerged Entry Nozzle (SEN).Tundish nozzle clogging is the disorder of casting process. It is the built-up of solid or semi solid material on a refractory surface which can become problematic during steel pouring, as it can affect the stream dynamics, reduce the pouring rate, and causes large agglomerated particles to be intermittently released into the liquid steel stream in severe cases. Because of the nozzle clogging , the casting speed is frequently decreased and even an entire cast is to be abandoned. Further nozzle clogging can give rise to both quality and productivity problems.In continuous casting , the argon injection method is used to prevent nozzle clogging whose effect is closely related to the migration of argon bubbles and the flow behaviour of the liquid steel in the nozzle. This review provides the summary of formation of clogging mechanisms, clogging detection methods, prevention of tundish nozzle clogging in quantifying the non composition related aspects by argon injection method and optimization of argon injection.

Keywords: Clogging mechanism, clogging detection methods, air aspiration, argon injection, argon optimization, submerged entry nozzle clogging, computational model.

I. INTRODUCTION

During the continuous casting of liquid steel, steel flows from the tundish to the mould through a submerged entry nozzle. This protects the liquid steel from reoxidizing in contact with the atmosphere. The flow rate is controlled with a gate or stopper rod to maintain optimum casting conditions. If the nozzle clogs and the flow control cannot make up for the reduced flux, the nozzle has to be replaced which means the production is interrupted. The clog build-up can also result in decreased steel quality as oxide particles can loosen from it, giving rise to rather large inclusions.Since the steelmaking processes occur at temperatures as high as 1,600 deg C, the interaction between the refractory materials of the SEN and the liquid steel is unavoidable. Hence, the SEN is required to have proper inertness, besides its moderate mechanical properties such as high temperature mechanical strength and thermal resistance. In general, the interaction between the SEN and the liquid steel can be categorized into three different mechanisms namely (i) the chemical reactions between refractory base materials and impurities in the nozzle and the liquid steel, (ii) the attachment of immersed non-metallic inclusions in the liquid steel, to the surface of the nozzle, and (iii) the erosion of the nozzle refractory materials. The first two mechanisms can cause clogging during casting process, which can limit the productivity by interruption of the casting process, restricting the number of charges per tundish, affecting the quality of the produced steels, and consequently increasing the cast product customer rejections.

II. LITERATURE REVIEWS

Clogging is a complex problem which has received a great deal of past study. Two comprehensive reviews of current understanding are given by Rackers [1] and by Kemeny [2] who recently summarized the many different causes and remedies with practical operation guidelines. Rackers calculates that a typical clogged nozzle contains 16% of the oxide inclusions that pass through the nozzle. Thus, it is beneficial both to reduce the number of inclusions, as well as to limit their transport and attachment to the nozzle walls. The transport of inclusions to the nozzle walls can be lessened by streamlining the flow pattern within the nozzle to minimize the frequency of contact of inclusions with the walls. In particular, slight misalignment , separation points in the flow pattern, turbulence, and fluctuations in casting speed are all very detrimental and should be avoided. In steel continuous casting, the tundish nozzle can control the quantity of liquid steel injected from the tundish to the mold as well as the melt flow behavior in the mold. When used in conjunction with mold flux, the tundish nozzle can avoid secondary oxidation of liquid steel, which has significant effects on improving the working conditions, stabilizing continuous casting operations, and preventing surface defects of slabs [3]. In the casting process of some steel grades, solid inclusions with a high melting point may adhere and deposit on the inner wall of the nozzle, causing nozzle clogging [4]. Once the nozzle clogs, there will be a bias flow in the nozzle, and the clogging matter may suddenly rush into the mold, which cause the violent fluctuations of level and slag entrapment in the mold [5]. Argon blowing is widely used to prevent nozzle clogging [6], including argon gas from the stopper rod, the tundish upper nozzle (TUN), and the submerged entry nozzle (SEN). Its effect is mainly through the following mechanisms [7, 8] : (1) preventing inclusions contacting the inner wall of nozzle, (2) flushing the adhered inclusions off the nozzle wall, (3) reducing the negative pressure in the nozzle and air inhalation at the nozzle joint, which can avoid reoxidation of liquid steel, and (4) preventing the reaction between the liquid steel and the nozzle refractory. Argon blowing at the tundish upper nozzle is to form a stable and continuous gas curtain between the inner wall of the nozzle and the liquid steel by adjusting the process parameters. This in turn inhibits the accumulation of inclusions such as $Al2O3$ on the inner wall of the nozzle and reduces the risk of nozzle clogging. Nozzle blowing argon technology, including the effect of argon blowing on melt flow behaviour, heat transfer [9–12], bubble distribution [13–15], and the fluctuation of steel/slag interfaces in the mold [16–20]. Thomas et al. [21] and Liu et al. [22] studied the influence of argon blowing on the flow field of the mold by the numerical simulation and water model experiments. They found that the argon bubbles entering the mold would change the flow field of the upper circulation flow, causing the flow impact point and circulation flow to move up. Liu et al. [17, 23] found that there were three different flow patterns in the mold according to the gas–liquid flow ratio. They further studied the three-phase flow of liquid steel/slag/argon gas in the mold via aEulerian multiphase flow model. The results showed that excessive argon flow rate would cause exposed slag eyes, which were mainly distributed in the area near SEN and the middle area of the wide surface of the mold. Argon gas increases the turbulence, which dislodges delicate inclusion formations from the nozzle walls and breaks up detrimental concentration and surface tension gradients near the nozzle wall [24]. It is noted that this mechanism may sometimes be detrimental by increasing particle contact with the walls and enhancing deposition. Argon gas reduces air aspiration and reoxidation by increasing pressure inside the nozzle [25, 26, 27,28]. Argon supplied through porous slits or into joints also helps by replacing air aspiration with argon aspiration. Argon retards chemical reactions between the steel and the refractory [29, 30].

III. CONCLUSIONS

1. As the nature of steelmaking produces large volumes of liquid containing inclusions, which all channel through a restricted nozzle opening, tundish nozzle clogging is likely to remain a chronic problem of every continuous casting operation.
2. Clogging serous issues can be solved by first identifying the cause, through analysis of the clog material. Solutions philosophies are based on minimizing inclusions by improved steelmaking practices, optimizing fluid flow and transfer processes, controlling steel alloy additions, slag and refractory compositions, improving nozzle material and design, and avoiding air aspiration.
3. As the casting speed increases, the concentration of bubbles in the nozzle decreases. The length of the bubble group distributed near the nozzle wall is extended, and the liquid steel velocity near the center and inner-wall of the nozzle both increases.

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